

Guided Design Search for the Sailor Assignment Problem

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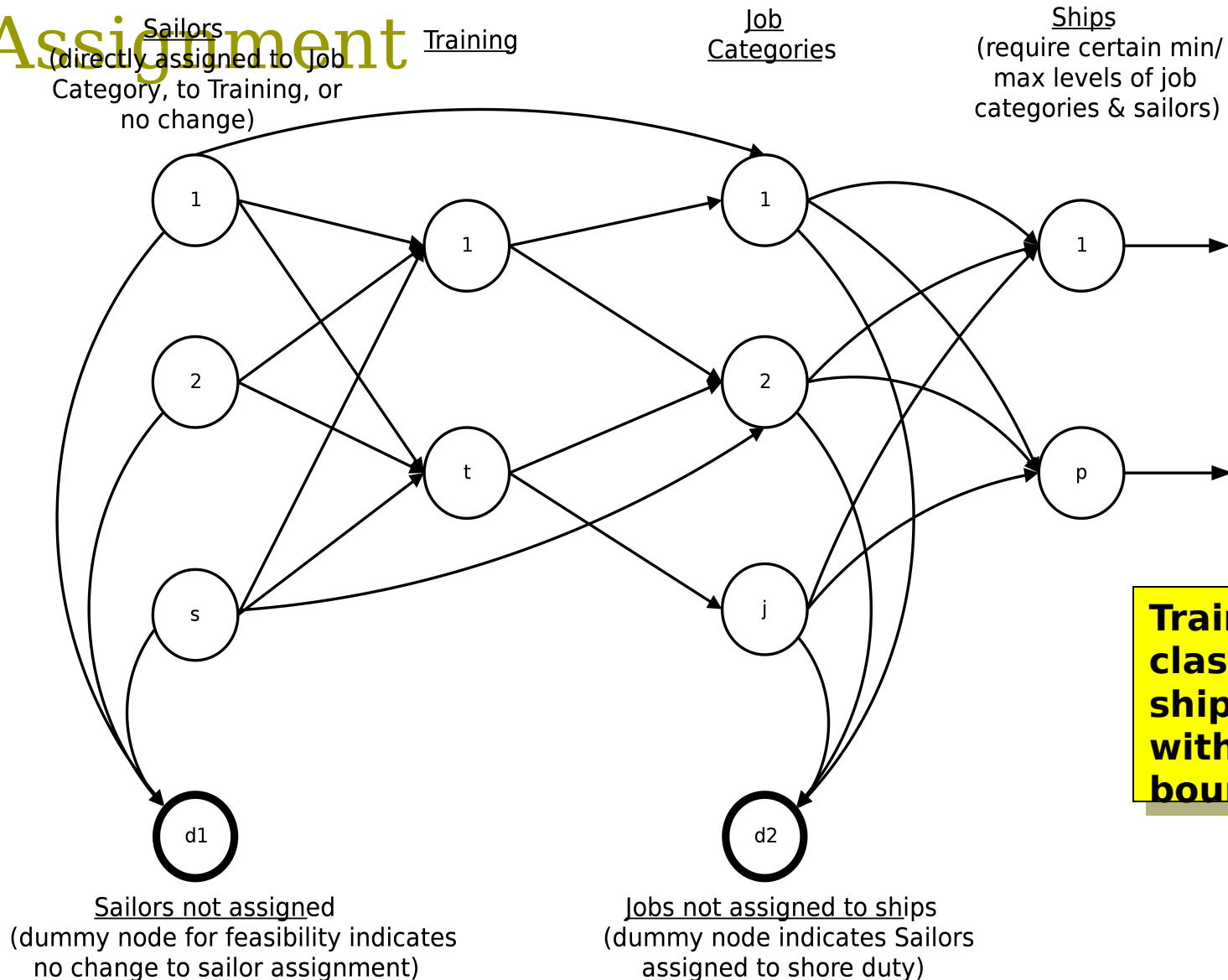
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Hearin Center for Enterprise Science

The Sailor Assignment Problem

- *Minimize the total cost of assigning sailors to:*
 - training (or directly to billets)
 - then to ships (or shore duty).
- *Maximize the number ships deployed* (ships require certain teams with job specialties)
- Modeled as a network flow problem with *interval bounds*
 - Interval bounds example: training classes do not “make” unless a minimum number of students are enrolled
 - Creates realistic, but difficult optimization problems

Network Flow Diagram for Sailor Assignment



Model Highlights

- Sailors are either: directly assigned to billets; sent to training for a billet; or no change to assignment
 - All choices have associated costs

- Training classes must “make” with a certain minimum / maximum # of students
 - Training qualifies a sailor for various # of job categories
 - “Making” a class has an associated bonus

Model Highlights

- From Job Categories, sailors are either assigned to ships or to shore duty
 - Jobs that “make” are rewarded
 - Each job category associates a cost with sea/shore duty
 - Individual Sea / Shore rotations are not explicitly modeled

- To be deployed, ships must “make” at certain levels of job specialty / sailor teams
 - E.g. **each job** for each ship requires a certain min/max number of sailors
 - **Each ship** requires a certain min/max **number of teams** having certain skills

What is Guided Design Search?

- A *preprocessing* technique that *identifies* important variables and *quantifies* their effect on total cost (i.e. the objective function value)
- Works by *sampling the solution space* using **Experimental Design techniques** (Taguchi methods & DOE)
 - As opposed to random sampling or changing-one-variable-at-a-time testing
- Can be used to reduce the searchable solution space by *setting a small number* of variables
 - E.g. the ship with the **greatest estimated beneficial effect** on cost is set as “required to deploy”

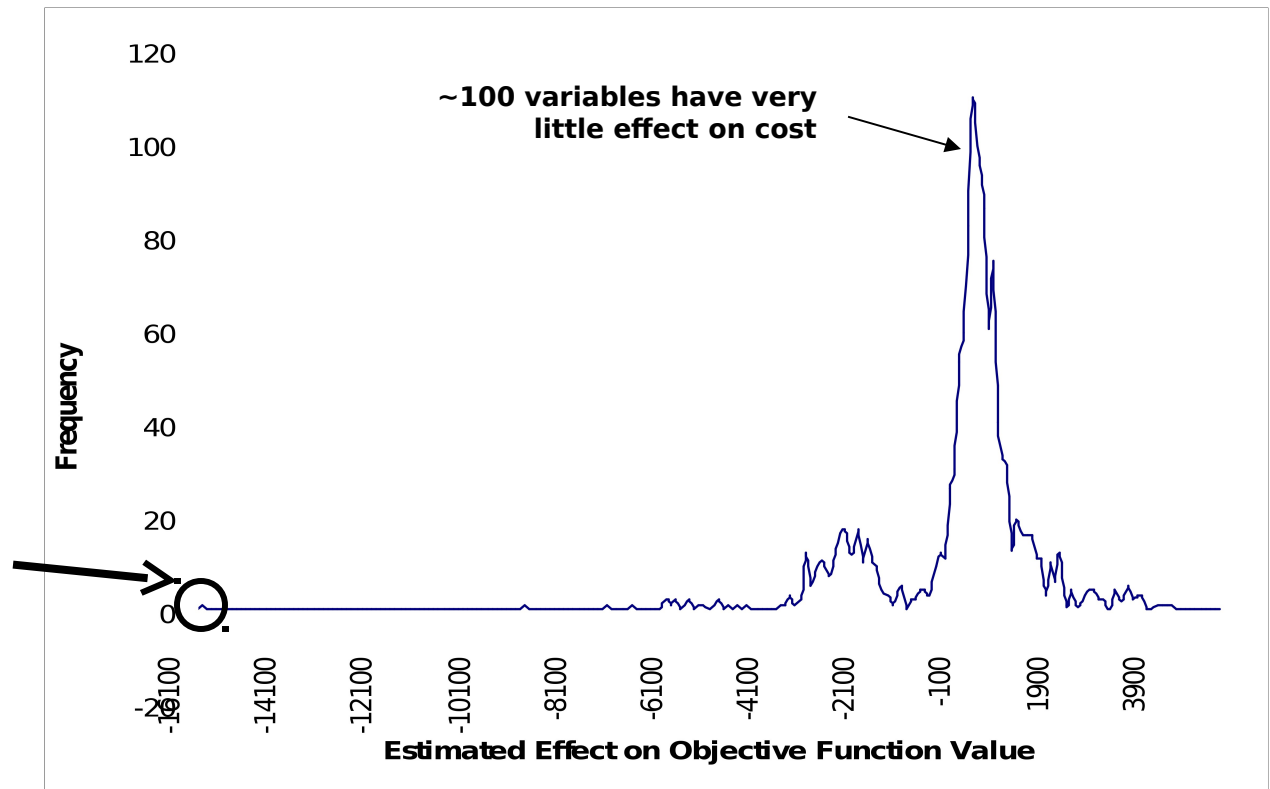
Results from GDS

Preprocessing

- GDS estimates the average effect of “turning on” a decision variable
 - With DOE, **every sample** is used in the calculation of the average effect
 - An equivalent number of **random** samples may generate biased estimates
- Variable effects quantified include:
 - *Individual sailor effects on cost*
 - *Average cost of deploying each ship*
 - *Average cost of filling a job specialty*

Frequency vs. Average Effect on the Objective Function

A few variables have a dramatic effect on total cost (these are the ones that are automatically selected in the optimization process)



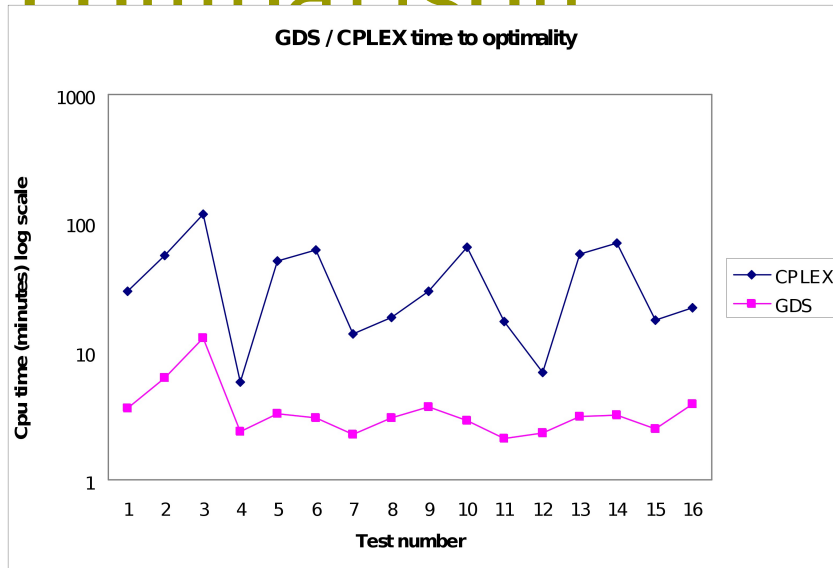
Majority of variables have "small" effect

GDS Optimization Test

Results

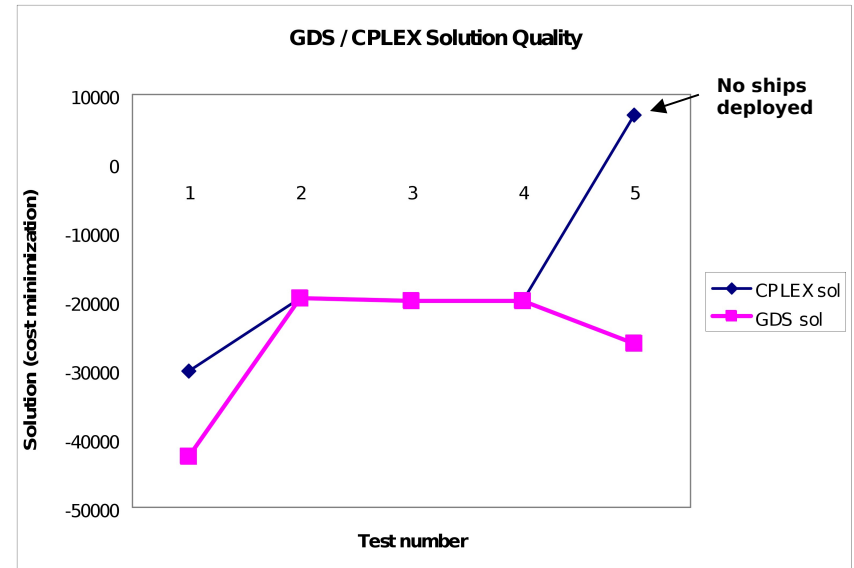
- Example data: **350 sailors** assigned to **500 possible jobs** on **20 ships** awaiting possible deployment
 - The training classes have various characteristics
 - E.g. # of classes, size of classes, # jobs training qualifies
 - There are various costs for: shore duty, leaving sailor with current assignment, change-of-station, ship deployment, etc.
- For problems *solved to optimality*
 - GDS was ~**10x faster** than CPLEX (the industry standard solver)
- For larger problems (*unsolvable to optimality* due to time & memory limitations)
 - GDS found **lower cost answers** than CPLEX

GDS / CPLEX time & quality comparison



**“Small” problems: 3945
binary variables (350
sailors, 10 training classes,
500 jobs, 20 ships)**

**Test numbers above are for
changes to the cost of assignments**



**“Large” problems: 7430
binary variables (350
sailors, 20 training classes,
500 jobs, 20 ships)**

Time Limit: 24 hours